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What do primary students know about light?: An investigation into misconceptions held by year 7 students in Western Australia

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WHAT DO PRIMARY STUDENTS KNOW ABOUT LIGHT?
AN INVESTIGATION INTO MISCONCEPTIONS HELD BY YEAR 7
STUDENTS IN WESTERN AUSTRALIA

By

Christine. A. Coulstock Dip. Teach. (Primary)

A thesis submitted in partial fulfilment of the
requirements for the award of

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at the Faculty of Education, Edith Cowan University

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USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

Abstract

This research examines misconceptions about light held by Year 7 primary school students. The subjects (n = 37) were selected from six schools in the north-eastern area of Perth, Western Australia.

An Interview About Instances approach was used in this research using instance cards specifically designed for this study. Misconceptions were ascertained and those held by 25% or more of the students were considered significant. Misconceptions were found in the understanding of the physical and the physiological process of sight, the relationship of light to colour, night vision in animals and the distance light travels under different circumstances. The misconceptions held by Year 7 students in this study were similar to those found in United States primary school students (Eaton, Anderson & Smith, 1984) and Western Australian secondary school students (Fetherstonhaugh, 1987).

Implications for teaching, teacher instruction and curriculum review are discussed and suggestions made for future research.

DECLARATION

I certify that this thesis does not incorporate, without acknowledgement, any material previously submitted for a degree or diploma in any institution of higher education and that, to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where due reference is made in the text.

signed

Acknowledgements

My thanks to Dr J. C. Happs who, as my supervisor, advised and guided the initial stages of this research, and to Dr M. Hackling, my other supervisor, for his advice and patience when I was writing this thesis.

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CHAPTER 1

Introduction

Research suggests that much of the learning that occurs in the classroom may not be that which the teacher assumes has taken place (Eaton, Anderson & Smith, 1984; Osborne & Freyberg, 1985). It has commonly been assumed that information is assimilated in the form in which it is presented, yet research indicates that the student's prior understandings about the topic are used to interpret instructions and generate idiosyncratic conceptions which might contain misconceptions about the topic. (Gilbert, Osborne & Fensham, 1982; Osborne & Wittrock, 1983).

Students construct a logical and coherent view of the world which often does not relate to the scientific view, and may have personal meanings for words used in science which vary from the scientific meanings (Osborne & Wittrock, 1983). Primary teachers often have limited scientific knowledge which may also be distorted by personal misunderstandings and lack of access to understandable background information (Osborne & Freyberg, 1985).

Problem Statement

Primary school students hold understandings about light which research suggests may be incorrect (Eaton, et al., 1984; Stead & Osborne, 1980). When they study

light as a high school topic these misconceptions may result in their inability to comprehend the concepts being taught (Karrqvist & Anderson, 1983).

Rationale for This Research

Students hold misconceptions during their primary schooling and the longer these misconceptions are left unchallenged, the more difficult it may be for the teacher to change them. Knowledge of misconceptions about light would be useful to the primary school teacher so that these may be addressed at an early stage.

A limited survey of primary teachers ($n = 27$) (Coulstock, 1990) indicated that some physical science topics were considered by teachers to be difficult to teach. This may indicate that children's misconceptions in these areas are less likely to be addressed. Light was considered to be one of the most conceptually difficult topics taught in the primary school.

Information regarding primary children's misconceptions in the physical sciences is still relatively limited and no studies have reported misconceptions about light as held by Western Australian primary students. This research adds to the existing body of knowledge.

Purpose and Research Questions

The purpose of this study is to explore and describe primary school children's understandings of light by means of individual interviews. More specifically the study addresses the following research questions:

Research Questions

1. What misconceptions do Year 7 primary children have concerning light?
2. How do these compare with findings amongst students in the U.S.A., Sweden, Italy, New Zealand and Western Australian high schools?

CHAPTER 2

Review of the Literature

Introduction

This review initially discusses concepts and how they are learned before considering misconceptions held by children and how these may affect learning. The discussion of scientific misconceptions commences with a review of the variety of misconceptions that have been found in science generally before examining research into misconceptions about light. It then considers how concepts may be probed and discusses the semi-structured interview as a method of inquiry.

Conceptions and How They are Learned

Novak describes concepts as arbitrary labels for events or objects. He considers most concepts "... acquire meaning through propositions which are two or more concepts linked together." (Novak, 1984. p. 607). The example given is that a *gram* is a *unit of mass*, two individual concepts which, when combined, provide a greater depth of meaning.

As an individual learns new ideas concepts are constantly being changed and expanded. Children gain considerable information about the world around them through observation and interaction. They gain understanding of words by listening and interpreting events, which can result in their understandings

usually relating to everyday meanings and not scientific meanings. They build a view of the world based on their experiences and knowledge which seems logical and intelligible to them but which often does not relate to the scientific view (Osborne, Bell & Gilbert, 1983; Osborne & Wittrock, 1983).

Novak (1984) considers that for meaningful learning to take place the learners must make a conscious effort to relate new information to knowledge that they already have. Novak uses the term "subsumption" to describe the way individuals integrate new ideas into current understandings. Subsumption is a personal process and the same information may not be integrated in the same way by two individuals resulting in different interpretations.

The Generative Learning Model described by Osborne and Wittrock (1983) indicates that, when information is presented to a learner, the learner's memory store and information processing strategies attend selectively to the input, ignoring some and selecting others for processing. Links are generated between the input and information in memory. If links are made which appear relevant to the learner but which are incorrect, the meaning will be distorted. The constructed meanings may be subsumed into memory, sometimes adjusting prevailing ideas and sometimes existing alongside them (Wittrock, 1974; Osborne & Wittrock, 1983). The stability of these

structures appears to depend on three things: they should be understood by the learner, they should be plausible and they should be useful (Hewson, 1981). Unfortunately, generated ideas which are not scientifically valid can often meet these criteria (Osborne & Wittrock, 1983).

Misconceptions, therefore, can arise in a variety of ways. They may be generated by the learner's own interpretation of events and experiences, they may occur when the word meaning used to interpret information is not the scientific meaning and they may arise when information presented is incorrectly linked to other ideas or not fully understood.

As indicated by Happs these understandings are referred to by researchers in a variety of ways:

Helm (1980) uses the term 'misconception' to mean those notions or ideas a learner may have about a topic, at any point in time and which are likely to be in need of modification or total replacement. Other terms, which have been used synonymously with 'misconceptions', are 'children's science' (Osborne, 1980); 'alternative frameworks' (Driver, 1981); 'intuitive knowledge' (Strauss, 1981); 'preconceptions' (Clement, 1982).

(Happs, 1984, p. 21)

Most researchers agree that misconceptions can have a significant impact on children's learning. Children come to the classroom with very strongly held views and, although they learn the concepts taught in order to answer questions and pass tests, frequently this learning remains separate from their own strong

understandings and is often not related to them. If the children are tested on their knowledge of the concept some time later it is possible that they will have reverted to their previous misconceptions (Osborne & Wittrock, 1983).

Misconceptions in Science

When children come to science classes with misconceptions it is suggested that any of the following learning outcomes may emerge.

1. The undisturbed children's science outcome.
This results in the children's original views remaining unchanged although they may incorporate some scientific language into their viewpoint.
2. The two perspective outcome. Here the children still retain their own view of the topic but they learn the teacher's view for test and examination purposes only.
3. The reinforced outcome. In this situation the child's interpretation of the information being taught results in the child's own ideas being reinforced.
4. The mixed outcome. The children's and teacher's views are mixed often resulting in contradictory information.

5. The unified science outcome. The children's view of the topic is similar to the scientist's view.

(Gilbert et al., 1982).

A considerable amount of research has already investigated misconceptions in science, and a wide variety of concepts has been covered including natural selection (Brumby, 1979; Deadman & Kelly, 1978; Greene, 1990), living and non-living (Angus, 1981; Brumby, 1982; Simpson & Arnold 1982; Stead, 1980), reproduction (Okeke & Wood-Robinson, 1980) and inheritance (Browning & Lehman, 1988; Hackling & Treagust, 1984; Kargbo, Hobbs & Erickson, 1980) in the biological sciences; physical change (Cosgrove & Osborne, 1981), chemical change (Schollum, 1981), chemical equilibrium (Gorodentsky & Gussarsky, 1988; Hackling & Garnett, 1985) and the particulate nature of matter (Doran, 1972; Novick & Nussbaum, 1981) in chemistry; and gravity (Ameh, 1987; Berg & Brouwer, 1991; Stead & Osborne, 1980), force (Berg & Brouwer, 1991; Helm, 1980; Osborne, 1980), air pressure (Sere, 1982) and light (Eaton et al., 1984; Guesne, 1976; Linke & Venz, 1979; Stead & Osborne, 1980) in physics.

Many of the investigations involved secondary children and research into primary children's misconceptions is more limited with findings often shown alongside those from studies with secondary

students. This makes discussion of primary results more difficult. Stepan, Beiswinger and Dyche (1986) investigated understanding of floating and sinking with students from kindergarten to college age and found that the level of understanding differed little between the youngest students tested and the oldest. The junior high school students were enrolled in science courses and the college students often had not only completed high school science but were also involved in tertiary science courses. They did find that the more mature students tended to use more scientific terminology but that this use was not generally accompanied by understanding.

Osborne (1980) investigated understanding of force in New Zealand students aged from 9 to 19 years old but the lack of systematic data by year make the information difficult to analyze. However, it is apparent that some understanding of force is carried through from primary school to university level without change as 30% of the students questioned at university level gave answers which "indicate some scientifically unacceptable use of language and/or physical understanding" (Osborne, 1980, p. 12). A further 10% gave at least one answer that could be classified as children's science.

It appears that many misconceptions appear in children of similar ages cross-culturally. Osborne (1980) related his findings to those in the United

Kingdom and France, and Osborne et al. (1983) stated that studies on similar topics in different countries demonstrate similar results. La Rosa et al. (1984) suggested that "mental representations in the field of optics have strong transcultural permanence" (p.388). Fetherstonhaugh, Happs and Treagust (1987) compared the misconceptions they found about light in Western Australian students aged between 13 and 16 years with studies from France, New Zealand, Sweden and the United States and again found similarities.

Misconceptions about Light

La Rosa et al. (1984) discussed light as it relates to most people's lives. Because light is an integral part their lives, people are aware that it is necessary for their sight but do not consider the factors involved in sight. People acknowledge in their speech that colour is a property of objects rather than a property of reflected light. They are aware that mirrors may reflect light but, students, when considering reflected images may not realise that incident light is involved as the object being reflected is not a light source.

The survey by La Rosa et al. (1984) covered a limited number of Italian secondary students but indicated that only 13% held a correct scientific concept of light. Misconceptions found included colour being the property of an object, that the colour

of light is added to the colour of an object, that the rules of reflection related to mirrors but not necessarily to light, and that light is everywhere and can go around objects. The possibility of seeing by visual rays is also briefly mentioned (La Rosa et al. 1984).

In 1980 Stead and Osborne investigated the concepts of light held by children in New Zealand. Initially they used the Interview About Instances approach with 36 children and then followed this up with a multiple choice questionnaire given to a further 370 children. The age range of the children was 10 to 15 years, but the majority of the children participating were 12 and 13 year olds. Similar misconceptions were found in many children of different ages, even though some of these children had studied light recently. Students were unable to correctly define how far light travelled and assumed that light travelled further at night than during the day. Some considered the distance light travelled depended on the size of the light source and felt that although a person could see light, that light would not necessarily reach the person. Most students were unable to explain how objects were seen.

Karrqvist and Anderson (1983) investigated conceptions of light with Swedish students aged from 12 - 15 years. Many students were unable to define

correctly how far light from car headlights would reach, nor were they able to explain refraction. They also had difficulty explaining the physical process of sight, with students suggesting the visual ray method of seeing. This method suggests that light, shining on an object, enables the viewer to see. Many students were unable to explain why light passing through red glass would result in a red glow on the wall with some students suggesting the red glass made the colour of the light change.

An investigation by Fetherstonhaugh (1987) with 13 to 16 year old Western Australian students found varying views of how far light travelled. Students suggested light would travel further at night. The physical process of seeing was poorly understood with most children considering that people see by looking. Many students considered that cats could see in total darkness and some also felt that people could see in total darkness. The research also looked at image reflection in mirrors. This was poorly understood as was the use of lenses to produce images. The majority of students were unable to explain the connection between light and colour and considered that colour was the property of an object. They were unable to offer the correct explanation of the change in the colour of light when it passes through a filter.

Eaton et al. (1984) in their investigation with Year 5 students in the United States discovered that

the text being used reinforced many children's misconceptions and only 22% of the students ($n = 52$) learned the correct concepts. Of the students who were investigated in depth all six believed that people see because light brightens objects and two, even after instruction considered that white light was colourless. It was also stated that "most students believe that colour is the property of an object rather than of light" (Eaton et al., 1984, p. 372). Although the report dealt mainly with these specific students it was reported that the other class members gave similar responses.

The research reviewed here demonstrates that many students do not hold a scientific understanding of light concepts. Many were unable to indicate how far light travels (Fetherstonhaugh, 1987; Karrqvist & Anderson, 1983; Stead & Osborne, 1980) and others considered the distance travelled depended on the size of the light source (Stead & Osborne, 1980). Some felt that although a person could see a light source the light from that source was not necessarily reaching the viewer (Stead & Osborne, 1980). Some students were not aware that light is needed for vision (Fetherstonhaugh, 1987) and some considered that people see by visual rays (Fetherstonhaugh, 1987; La Rosa et al., 1984). The physical process of seeing was poorly understood (Eaton et al. 1984; Fetherstonhaugh, 1987; Karrqvist & Anderson, 1984). The relationship between light and

colour was not understood (Eaton et al., 1984; Fetherstonhaugh, 1987; La Rosa et al., 1984), neither was the effect of a coloured filter on white light (Featherstonhaugh, 1987; Karrqvist & Anderson, 1983). Students felt that light was able go around objects (La Rosa et al., 1984) and refraction (Karrqvist & Anderson, 1983) and reflection (Fetherstonhaugh, 1987; La Rosa et al., 1984) were not understood.

Primary School Science in Western Australia

Although the research relating to primary children's misconceptions is limited, it is felt they may hold similar misunderstandings about the basic concepts related to light. In Western Australia, topics on light may be encountered in Years 2, 3 and 7 and light-related topics are taught in Years 1 and 5. Although there are no specific science topics on sight this is taught as a health topic in Year 5.

The concepts about light that are included in the Western Australian Science Syllabus (Curriculum Branch, Education Department of Western Australia, 1983) are:

Pre - Primary	The sun provides light and heat.
---------------	----------------------------------

Junior Primary	Light and heat come from many sources, of which the most important is the sun.
	Light and heat may be reflected by objects, may pass through objects and may be absorbed by objects.
Upper primary	Light, heat and sound can be produced in various ways.
	(p. 39).

The Western Australian syllabus offers three alternatives for teaching, one using the Education Department materials, one using a mixture of Department and commercial materials and one using teacher produced materials. A variety of commercial materials are listed in the Science Handbook, K - 7 (Curriculum Branch, Department of Education of Western Australia, 1984), although no suggestions are made for teacher generated activities.

Education Department curriculum materials are generally available in schools and consist of a Teacher's Guide and workbooks for each year level. A complete list of light related topics in the publications is shown in Appendix 2.

The activities and information available are not always clearly explained. In the Year 3 activities a

variety of methods are used to produce rainbows with the materials then moved to a shady spot so the spectrum can no longer be seen. These activities "should develop children's awareness that there is a relationship between light and the spectrum" (Curriculum Branch, Education Department of Western Australia, n.d., p. 74). No information is provided to enable the teacher to understand the relationship.

Background information is available in the Teacher's Source Books for Year 4 - 7, but is not always in a form easily understood by teachers with a non-scientific background.

Light falling on a surface will be transmitted through, absorbed by, and reflected from the surface. The direction, dispersion, intensity and colour of the reflected light will be affected by the texture and colour of the surface, and the angle and intensity of the light. Children may find that smooth, light coloured surfaces tend to reflect more light than rough, dark coloured surfaces. Non-reflected light is transmitted through or absorbed by the surfaces.

(Curriculum Branch, Education Department of Western Australia, 1980, p. 68)

The Year 5 Health Syllabus looks at eyes and sight with the only focus question relevant to the study in the Teacher's Notes being "What is the function of the eye?" (p. 143) The notes refer mainly to the physiological process of sight with references to the physical process of sight being ambiguous.

The function of the eye is to receive rays of light that contain images.....

(p. 144)

The black pupil of the eye is a hole (the aperture) through which light, and hence images, travel to register upside down on the retina (the light-sensitive film).

(p. 145)

Investigating Conceptions

Concepts held by people are indiosyncratic and to develop an in depth understanding of them the researcher must not only obtain answers to direct questions about the concepts but must also be in a position to probe the students to find reasons for their views or to elaborate on their understandings. In order to do this the researcher must be able to pursue ideas or comments presented by the learner. Hook (1981) has argued that the most effective way to "...gather information about people's knowledge, about feelings and attitudes, about beliefs and expectations, about intentions and actions and about reasons and explanations.." (p. 136) is an interview. The interview produces in depth data and is flexible allowing the interviewer to adapt to any interviewee (Gay, 1976).

In the Interview About Instances approach, the questions are defined and always presented in the same sequence, but the researcher allows the interview to progress according to students' responses to gain a greater insight into the way they think (Gilbert et al., 1981). The application of an Interview About Instances technique to this research is described in the next chapter.

CHAPTER 3

Methodology

Selection of Data Gathering Technique

This is an exploratory study designed to ascertain the understandings Year 7 students have about light. It was, therefore, essential for the researcher to talk to students to clarify any ideas they might have and compare these with those found in the few previous studies identified. Students could then be asked to elaborate on and explain reasons for their views. It was also necessary for students to easily comprehend the concepts being presented and, rather than use explanations, a visual method of presentation was seen to be appropriate.

In view of these considerations it was decided to use individual interviews with the students based on the Interviews About Instances approach described by Gilbert, Watts and Osborne (1981). This technique would allow concepts to be presented as pictures for which only a brief explanation is needed. A focus question is used to initiate discussion and the interviewer then uses non-evaluative comments and questions to elicit further information. Pencil and paper tests were considered inappropriate as they would not provide an opportunity to discuss students' understandings.

Development of Interview Instrument

Although some research has been conducted into children's knowledge about light, no instrument appeared to be available for primary children which covered all areas being examined. Therefore, after analyzing previous research and discussion with those experienced in teaching about light, appropriate concepts areas were identified and a series of line drawings produced to depict instances which provided the basis for the interviews. The concept areas probed were:

- (1) How do people see?
- (2) Is it possible to feel someone staring at you?
- (3) Can animals see in the absence of light?
- (4) What is the connection between light and colour?
- (5) How far does light travel?

In order to probe selected topics in depth, cards depicting differing instances were prepared for some areas. Figure 1 presents a sample card used to probe the concept "How far does light travel."

A pilot study was conducted with ten students using the cards. Interviews were recorded and interviews transcribed verbatim using the format

described in Gilbert et al. (1981). As patterns emerged data were recorded on data summary sheets.

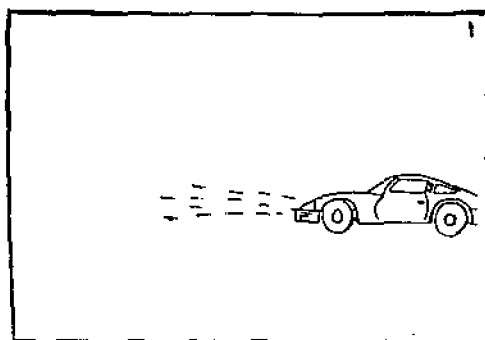


Figure 1. Card used to probe the concept "How far does light travel".

Analysis of the pilot study data indicated that it was not necessary to modify the cards for the main study. It was decided to include an extra question regarding the origin of the colour of objects as this appeared as a significant misconception in the literature.

Subjects

Thirty seven Year 7 students were selected from schools in the north-eastern area of Perth. Interviews were conducted at the end of the school year to ensure sufficient time had been allowed for Year 7 curriculum topics on light to be covered.

Schools were chosen by reference to Ministry of Education District Office lists of schools in the north-eastern area of Perth. They were selected on the

basis that they needed to cover as wide a range of population and socio-economic areas as possible. The areas chosen for the research included State Housing Commission areas, middle and high income areas and one school was part of the Priority Schools Program in a low socio-economic area. Table 1 shows details of the schools used.

Table 1
Details of Schools Used in Interviews

School	Type	Number of yr 7 classes	Number of students interviewed
1	State	4	12
2	State	1	6
3	State	2	6
4	State	1	3
5	Private	1	4
6	State	2	6

If there was more than one Year 7 class in a school, students from each of the classes were interviewed. A maximum of six students was randomly selected from each class and, although only six schools were used, 11 classes were covered ensuring the research did not represent only the idiosyncratic teaching of one or two teachers.

Procedure

A venue within the school which would promote relaxed informal discussion was selected for the interviews. Parental consent was obtained prior to interviewing the students.

Children were interviewed individually using the Interview About Instances approach (Gilbert et al., 1981). The maximum number of children interviewed in any one session was six and all interviews were audio-taped, with each interview being recorded on a separate tape side. The interviewer sat alongside the student, introduced herself and explained that she was not looking for the right answers but was interested in ideas that the child might have. This was re-iterated throughout the interview as necessary. The presence of the tape recorder was explained. Interview cards were always in the same order and the researcher introduced each card with a brief explanation and the appropriate focus question. The direction the interview took depended on the student's responses, and clarification and elaboration was requested as necessary. Previous responses or cards were referred to as required.

Research Consistency

Research consistency was sought by:

- (1) The researcher conducting all interviews.
- (2) Trialling of the instrument with a group of students of the same age as the target population prior to its use in the field. One interview was observed by an experienced interviewer to ensure the interviews were being conducted effectively.
- (3) Audio taping all interviews.
- (4) Supplying teachers with a list of random numbers to be used to select students from the class roll.

In addition schools were selected to give as wide a range of abilities and backgrounds as possible to increase the generalisability of the findings.

Confidentiality

Although students' first names were used during the interview, a code was used to designate students in all written work, consisting of a number indicating the number of the interview, a letter indicating male or female and the number seven showing that the child was from a year seven class. This information was shown on the tape case together with the date of the interview.

The name of the school, although required for initial research, has been omitted from any written work and does not appear on tapes.

Assumptions Made in This Research

1. That the students selected were representative of year 7 students in Perth.
2. That the interview environments were non-threatening to all the children.

Limitations of this Research

1. The small size of the research population which was, however, felt to be representative of the views of children in that area.
2. The limited geographical area accessible by the researcher in which the schools were found. The range of schools chosen was felt to be representative of the schools in Perth, Western Australia.

Analysis of Data

The information from the interviews was recorded on record sheets where only data relevant to the investigation were recorded together with explanatory comments made by the students. Data consisted of yes/no responses, colours, distances and, for concept area 1, the student's explanation. The responses were

collated so that answers to cards relating to one concept area were grouped.

Responses to each focus question were analysed separately and answers coded to indicate the type of response. Tables were compiled showing the frequency of student responses. Misconceptions held by 25% or more of the students were considered significant and these have been reported in the next chapter.

CHAPTER 4

Results

Introduction

Student conceptions of light were probed using 14 cards and their associated focus questions. Students' responses to these problems have been collated into five concept areas. Table 2 shows these concept areas and the cards used to probe understanding in those areas.

Table 2

Concept Areas Showing Relevant Topic Cards	
Concept area	Topic card numbers
1. How do people see?	2
2. Is it possible to feel a person staring at you?	5
3. What is the connection between light and colour?	8,9,10,11,12
4. Is it possible for some animals to see in the absence of light?	3,4
5. How far does light travel?	1,6,7,13,14

This chapter presents those data related to the concept areas. For each area the following are presented: the focus question, the correct scientific view, frequency of student responses to the question, and categories of misconceptions for which a

description of the misconception is given together with illustrative quotations.

The quotations show students' speech in normal print and the interviewer's in italics. A line of dots (.....) indicates a pause for thought by the speaker. The subject identification codes consist of a number indicating the interview number, a letter indicating the sex of the student and the number seven showing that the student was from a year seven class.

Generally the only misconceptions discussed are those central ones held by at least 25% of the students.

Concept Area 1: How Do People See?

Focus Question

What is happening so that the person can see the tree?

Scientific view. Light rays fall on an object and are reflected into a person's eyes enabling the person to see the object.

Student Responses. Of 37 students only 8% gave an acceptable explanation of light being reflected into the person's eyes.

Misconception 1(a). The sun gives light enabling people to see (35%).

The sunshine makes it light so he can see.

19F7

Well, the sunlight's helping him. *(Okay, how does it help?)* Well, it provides light.

31F7

Misconception 1(b). Sunlight/light brightens/lightens things so they can be seen (57%)

Light *(Okay, what does the light do?)* Brightens the earth so you can see the tree.

11M7

Um well, the sun's lighting up all, all the country. That makes it so he can see the tree.

20F7

Focus Question

Do you know what actually happens so that people can see? What happens with their eyes?

Scientific view. Light reflected from the object into the eyes is focussed onto the retina stimulating the photo-receptor cells. An electrical impulse is then transmitted to the brain via the optic nerve and the image is seen by the brain.

Student responses. Of 36 students, 8% gave acceptable explanations of the vision process, 39% gave incorrect explanations, and 53% were unable to offer any explanation. There was little consistency in responses, and no specific misconception could be defined.

Generally, students' responses related only to the eyes or eyes/brain being involved in the process.

His eyes. *(So he uses his eyes to see?)* Eyesight, yeah.

15F7

You focus on it.

19M7

He thinks and he can see with his eyes.

32F7

Some responses demonstrated obvious confusion:

Um, the sun goes through the eye and sends a message to the brain I think and then he's able to see. Something like that.

39F7

Your eyes send a message to your brain which then er sends it back down again, it comes back through your eyes I think.

41F7

I know they've got a sort of series of eyes, probably get to your brain and then tell you what it is. *(They go through a series of eyes.)* Yeah. *(Before it actually reaches your brain.)* Yeah.

43F7

Concept Area 2: Is it Possible to Feel Someone Staring
at You?

Focus Question

Is there any way the person in front knows that the person behind is staring at them?

Scientific view. It is impossible to feel someone staring at you.

Student responses. Thirty-five percent of the 37 students said the front person would know someone was staring at him/her, 3% were unsure and 62% (24 students) felt the front person could not feel that someone was staring at him/her.

Those who gave a negative or undecided response were then asked the same question but in a different format:

"I've heard people say 'I could feel someone staring at me'. Do you think that can happen?"

Of 24 students 50% still considered it was impossible, 8% were uncertain and 42% said that it was possible to feel someone staring, resulting in a total of 62% of all students having this belief,

Misconception 2 (a): It is possible to know that someone is staring at you even if you are unable to see that person (62%).

When students offered a positive response they were asked to explain how this is possible.

....ummmm might, depends if they've got extra sensory perception. *(E.S.P. Yes. Okay, so you feel there is a possibility?)* Mmmm.

12M7

Yeah, um, yeah, I read that in a book too. Maybe it's because of the um um when it was in um prehistoric times, well if there was a slow moving creature like the ones that depend on that like um sabre tooth tiger which would have lived then, maybe they needed that special sense. *(So it might be a sort of sense that we don't use now but it's still there?)* Yeah.

22M7

Fifty-one percent of students described personal experience of the feeling.

(Have you ever felt anybody staring at you?) Mmmm.
(How does it feel?) Feels funny because you're just sitting there and you're minding your own business and then all these people looking at you and you sort of look around and getting a bit worried.

35M7

(Have you felt people staring at you?) Yes. *(What*

does it feel like?) Well, it feels like there's something wrong and you try to check and make sure there's nothing wrong with you.

38F7

Concept Area 3: What is the Connection Between Light and Colour?

Focus Question

If you look through red/green cellophane at an illuminated light globe what do you see?

Scientific View. White light is made up of a mixture of many colours and the presence of a coloured filter between the eyes and a light source only allows light waves of that colour (a specific wavelength) to reach the eyes, and the light source would appear that colour.

Student responses. Of the 37 students 95% said the light globe would appear red when looking through the red cellophane and 5% gave an incorrect response. When asked about the green cellophane, 97% of students stated the light globe would appear green and 3% gave incorrect response.

Focus Question

Why does the light globe look red?

Scientific view. The colour of the light globe appears to change because the red cellophane only allows red light (of a specific wavelength) to pass through.

Student responses. Of 37 students 97% gave incorrect explanations and 3% were unable to offer any answer.

Misconception 3(a): The red cellophane makes the light globe look red.

Students generally stated that the globe looked red because the cellophane was red, although some students gave vague explanations.

Because the particles are red um things in it, turn it like glasses, they turn it, if you had red glasses you'd see everything red because you can still see through it but it's red.

23M7

Because the colour of the cellophane is red and um like when you look when you look through it um say you covered it over your face you wouldn't be able to see any light at all and you just see everything would go um, light that you could see would be red.

26F7

Focus Question

If you were in a dark room and you had a really good torch shining a clear white light and you shone it on a red box, what would you see?

Scientific view. When white light is shone on to a red object, the object absorbs all the wavelengths associated with white light except red which is reflected.

Student responses. Ninety-two percent of the 37 students stated that the box would look red, 8% considered the colour would change.

Focus Question

If we were still in the dark room and we shone a red light on the red box, what would we see then?

Scientific view. When red light is shone on to a red object and no other light is present, the object would still look red as only the red wavelengths would be reflected.

Student responses. Of 37 students, 84% said the box would look red, 13% thought that the colour would change and 3% were unable to suggest an answer.

Fifty-eight percent of students who responded "red" considered the quality of colour might change, with the majority considering that it would look darker.

Focus Question

If we were still in that dark room and we shone a green light on the red box what would we see then?

Scientific view. When green light is shone on to a red object and no other light is present, no red light is available for reflection and the object absorbs all light incident on it therefore appearing black.

Student responses. Of 37 students 92% gave an incorrect response and 8% were unable to offer any answer. Of the incorrect responses, 15% students thought the box would look red, 15% thought it would look green, 26% felt it would be a mixture of red and green, and 44% suggested a variety of other colours.

Misconception 3(b): A red box will either look red regardless of the colour of the light or the colour will change to that of the light.

... Um ... I don't know, just a red box and a bit of green shadow.

16M7

A red box with green surroundings.

43F7

A green, a green a, yeah, dark green, well, the box would be green I guess, shining a green torch on it and the beam would be green.

31F7

Misconception 3(c): When a green light is shone on to a red object the colour of the object and the colour of the light mix to produce a new colour.

Most students considered the colour of the object would change to a colour that was neither red nor green. Some suggested a mixture of red and green but were unable to decide the resultant colour, and others gave specific colours.

Well the red wouldn't be as clear, it'd be a reddish green colour and it'd have a green glow around it.

38F7

Um, you'd probably see still a yellowy green sort of circle in the middle and I suppose you'd see a sort of mixture of green and red, not pure red or pure green but sort of like a mixture of both of them.

41F7

Umm a purple box.

44F7

Focus Question

There's a (colour/object) over there. Can you tell me why we see it as that particular colour? Note: The objects chosen, and consequently the colours, varied with the locations of the interviews.

Scientific view. Objects absorb some wavelengths and reflect other wavelengths of light. The reflected wavelengths determine the colour seen.

Student responses. Of 37 students 72% stated that it was because the object was that colour, 12% demonstrated limited knowledge and 16% were unable to explain.

Misconception 3(d): Colour is the property of an object.

Students generally stated that an object was seen as a specific colour because it was that colour or had been painted or dyed that colour.

Probably just the paint that's on there, the colour that's on it.

16M7

Um, because when it's dyed it has a red dye so the white material becomes red.

38F7

No student offered a correct explanation although some demonstrated a reasonable grasp of the concept.

The sun has got in the colours of it and if you say have something and you put one of er those things, triangular prism, you get all different colours so if you had red you'd be reflecting all the colours um darker than that so you get that colour. *(We've got red shining on it out of the white light, what's happening to all the other colours?)* The light colours are absorbed and the others are reflected so you get that colour.

Concept Area 4: Can Animals See in the Absence of
Light?

Focus Question

Can an owl/cat see a mouse at night? Note: This question was used to obtain students' initial responses. To avoid ambiguity it was succeeded by more specific questions.

Scientific view. In total darkness no animal can see. However, owls and cats, being nocturnal animals, require a much lower threshold of light than humans to be able to see.

Student responses. Of 37 students, 94% said an owl could see at night, 3% said it could not see at night and 3% were unable to offer an answer. Seventy-eight percent of the 37 students felt a cat could see at night, 19% said it could not see at night and 3% were unable to offer an answer.

Misconception 4(a): Owls and cats can see at night.

The question did not qualify the quantity of light available but the majority of children felt that owls and cats would be able to see a mouse at night. The reason cited for the owl's ability was generally that it was nocturnal and hunted for its food at night. Although students felt that the cat could see a mouse at night, they often commented that it could not see as well as the owl.

Focus Question

If there was a full moon would it make it easier or harder for the owl/cat to see or wouldn't it make any difference?

Scientific view. The presence of a light source makes it easier for an owl or cat to see at night.

Student responses. Table 3 shows student responses to the focus question.

Table 3

Student Perceptions (n = 37) of the Effect
of a Full Moon on the Vision of an Owl
and Cat, by Percentage

	Easier	Harder	No diff.	Didn't know
Owl	27	27	40	6
Cat	70		27	3

Misconception 4(b): The light from the moon makes it harder for an owl to see.

A number of students considered that, because owls slept during the day and preferred the dark, the presence of a moon would hinder the owl.

Umm, not so good because there's more light and he's better at seeing in pitch darkness.

20F7

Um, probably harder. (*Why would it make it harder?*) Well, he sees better in the dark.

33M7

Misconception 4(c): The light from the moon makes no difference to an owl's or cat's ability to see.

Owl.

It'll help people to see better but it probably wouldn't make any difference to the owl.

35M7

Cat.

I don't think it would make much difference in the cat either.

39F7

Focus Questions

If I took that owl/cat and put it in a room with no windows and the doors were shut tightly so there was no light getting in at all, could the owl/cat still see the mouse?

If I took you and put you in that pitch dark room, remember there is no light getting in at all, could you see anything?

Scientific view. It is impossible to see in the absence of light, and a prolonged stay in the lightless environment will not change this.

Student responses. Table 4 shows the students responses to the various categories of the focus question.

Table 4

Students Views Whether an Owl/Cat/Person
Could see in a Lightless Environment,
by Percentage

	Number	Yes	Probably	No	Didn't know
Owl	37	49	11	35	5
Cat	37	19	5	73	3
Person	36			97	3

Those who responded negatively or were unsure were then asked: "If I left the owl/cat/person in there for 10 - 15 minutes would that make any difference?"

Table 5 shows students' responses to this question.

Table 5

Student Responses Indicating Whether an Owl/Cat/
Person Could See After 10-15 Minutes in a
Lightless Environment by, Percentage

	Number	Yes	No	Not sure	Didn't know
Owl	19	64	10	16	10
Cat	30	60	17	13	10
Person	36	58	31	8	3

Misconception 4(d): Some animals can see in the absence of light.

Students felt an owl was more likely to see immediately than a cat and some suggested that the cat would not be able to see as well as the owl.

Not as good as the owl I don't think.

18F7

Probably, but not as well as the owl.

38F7

Misconception 4(e): If a person or animal stays in a lightless environment for a period of time their eyes will adjust and they will be able to see.

Most students in each case considered that the subject would be able to see after a period of time.

Owl.

Probably after a while. (*Had to wait a little while. Okay, so, after a while what happens to the owl's eyes?*) It gets used to the dark.

21F7

Yes. (*Okay, why would he be able to see after a while?*) Because he'd get used to it after a while. (*What would he get used to?*) The darkness.

34M7

Cat.

Yes, it might because its eyes would adjust.

20M7

Person.

Might be able to just make out ... the walls or whatever's there. *(You might be able to see outlines or something.)* Yeah. *(Okay, what happens to make you able to see after 10 or 15 minutes?)* Your eyes get adjusted to it ... we let more light in so we can see with the light that's around. So we can see a little bit more. *(Okay, now remember I said it was a completely dark room.)* Yeah. *(So you think there'd still be some light in there so you'd be able to see?)* ... After a little while I suppose.

17F7

Five students offered unusual ideas of why some animals can see at night. Four referred to the animal's glowing eyes.

(Why can the cat see the mouse? Is it the same as the owl?) Umm, no, not really, but the cat's eyes like light up at night. *(They light up. What happens when the cat's eyes light up?)* ...Ummm. *(I mean how does that help the cat see the mouse?)*ohhhr ... the like, the eyes are more brighter than the other animals. *(Yeah,)* So it's nocturnal. *(Yeah. Okay, does the fact that the cat's eyes are*

bright at night, um, does it sort of reflect on the mouse or does it help it see the mouse?) Help it see the mouse.

13M7

One other student considered that an owl's eyes gave off a heat ray.

He's um, like, um throwing heat out and whatever reflects comes back to him. He can tell if there's an object around or whatever. (Okay, and he uses his eyes to do that?) Yeah.

12M7

Concept Area 5: How Far Does Light Travel?

Students had difficulty visualising distances. Where possible the interviewer demonstrated the distance suggested, but long distances were impossible to check and this should be considered when evaluating the results.

Focus Question

How far do you think the light from the car headlights/candle/television/mirror will reach?

Scientific view. Light will continue travelling until it hits an object. The strength of the light source has no effect on the distance travelled.

Misconception 5(a): Even if there is nothing in the way which would stop the light, light will only travel a limited distance.

All students interviewed felt that there was a limit to the distance light from most sources would reach, although the distances varied. Table 6 shows the ranges of distances suggested by the students.

Table 6

Student Perceptions (n = 37) of the Distance Travelled by Light from Various Sources by Percentage

Source	Distance travelled in metres					
	0	<1.0	1.1-10	11-100	101-1000	>1000 Infinity
Car lights. night			32	51	11	3 3
Candle, day inside	11	57	16		3	
Candle, night inside		19	51		3	
T.V. inside		27	57	5		
Mirror	3	22	35	3		

Note. Students not shown on the chart did not clearly define the distance the light would travel.

Misconception 5(b): The strength of the light affects the distance it will travel.

Students were not asked to explain why the distances suggested for the different light sources varied, but it appears from available data that

students generally felt that light from a weaker light source would not travel as far as light from a stronger light source.

Ninety-five percent of students suggested distances which indicated that light from car headlights would travel further than light from either the television, the candle during the day or the candle at night. Seventy-six percent of students indicated from their responses that light from the television would travel further than the candle during the day and 49% indicated that light from the television would travel further than the candle at night.

Focus Question

If I was further away than (*distance*) would I still be able to see the television/mirror/candle?

Note: The distance quoted would be the distance the student had suggested light would travel.

Most students (n = 31) were asked about the television, two about the candle and one about the mirror.

Scientific view. If an object is visible to an observer the light reflecting or emanating from that object must reach the observer.

Student responses. Of 34 students 97% stated the object would still be visible even if the light did not reach that far, and 3% stated it would not be visible.

Misconception 5(c): It is possible to see a light source without the light reaching you.

Students were generally very sure that, even if light from a source object reached a limited distance, a person standing further away would still be able to see the object.

(Okay, if the person moved quite a long way away from the television, not just your 15 metres, moved further back, the light wouldn't reach him?)
No. *(Could he still)* He could still see the T.V., yeah, but it'd be a blur. *(It would be a blur.*
Okay, he'd know the television was on but the light wasn't actually reaching him?) No.

12M7

Focus Questions

If we took the candle/television/mirror outside during the day would it make any difference to the distance the light travels? What sort of difference would it make, would it travel less far or further? What is happening to make that difference?

If there was a very bright moon would that make

any difference to the distance that light from the headlights travelled? What is happening to make that difference?

Scientific view: The presence of a high ambient light intensity does not change the distance light from a source will travel.

Student responses. Generally the students felt that light would travel less far if there was a second light source present. If a candle was moved from inside to outside 58% of students said the light would travel a shorter distance. If a television was moved outside 62% of students considered the light would travel less far and if the mirror was moved outside 25% felt the light would travel less far. Forty percent of students felt that the light from the moon would reduce the distance the light from the car headlights would travel.

Misconception 5(d): The distance light can travel diminishes if there is another light source available which appears to be stronger.

This topic was usually only discussed when considering the distance the light from the car headlights could travel and the distance the light from the candle could travel.

Car Headlights.

Because there's more light and it's reflecting off the road and it'll block some of the light from the headlights.

12M7

Um because there's already light coming from the moon.

27M7

Candle.

Because at night time there's just one light which is just going to be the candle light and it's all dark around outside and during the day, because there's lots of light it's like shining a torch during the day, you can't, the torch won't have any effect on it. *(Okay, what does the light do to stop the light from the candle travelling anywhere? Do you know?)* Absorb it. *(It just sort of absorbs it.)* Yeah, just like mixing too.

19M7

Well, because the sun's shining you can um you can hardly see it because you don't really need the light.

31F7

CHAPTER 5

Discussion

Most of the misconceptions that have been found in this research have been previously reported in overseas studies or in research in Western Australian high schools. Origins of identified misconceptions were not ascertained in this study but in some instances it is possible to speculate as to their source.

Concept Area 1: How do People See

The majority of students (92%) had little concept of the physical process of sight. Fetherstonhaugh (1987) found that 60% of Western Australian high school students had misconceptions in this area and Karrqvist and Anderson (1983) found 99% of the younger Swedish students she surveyed had similar difficulties. Similar findings were reported by La Rosa et al. (1984) with Italian students, Eaton et al. (1984) with elementary students in the U.S.A. and Stead and Osborne (1980) in New Zealand. The majority of students (92%) had little concept of the physical process of sight. All students recognised that light was necessary for sight but 57% felt that light brightens things so they can be seen, an understanding also reported by Eaton et al. (1984), and 35% considered that people could see because light was present.

The Western Australian science curriculum's many topics on light and shadows do not appear to be addressing this concept effectively and it is possible that some misconceptions may be reinforced by ambiguous text in the science and health curriculum materials. One could speculate that the lack of understanding is not only due to the lack of appropriate teaching materials but also because many adults and teachers with a non-science background are unaware of the physical processes associated with sight. Everyday language may also reinforce the misconceptions with statements such as "The sun is shining on the tree," or "Turn on the light so we can see" indicating that the light is lighting up the object enabling the viewer to see it.

Thirty-nine percent of students gave an incorrect explanation of the physiological process of vision and a further 53% could offer no explanation. This topic is covered in the Year 5 Health Syllabus.

Concept Area 2: Is it Possible to Feel Someone
Staring at You?

When questioned on this concept initially using only the Instance card 35% of students felt it was possible to feel someone staring at you. However, when the question was re-stated in terms of personal experience a further 10 students considered it possible, making a total of 62% who considered it was

possible to feel someone staring at them. Many students quoted instances of personal experience.

Fetherstonhaugh and Happs (1988) found that 90% of Year 8 students, asked in a classroom situation, also considered this was possible. These students also thought there was "something" coming from the eye when looking at objects and this was also found by La Rosa et al. (1984) and Karrqvist & Anderson (1983) in their research. Few students interviewed in this study thought that there was some form of ray coming from the eyes. Most could offer no explanation why a person's stare could be felt although one felt it was a "left over" sixth sense.

This misconception is not treated in any way by curriculum materials and is possibly unconsciously reinforced by teachers who stop and stare at a student who is not attending until that student realises something is amiss and looks up. The students may consider that they "felt" the teacher staring whereas the general classroom "atmosphere" in fact alerted them to the stare of the teacher. This misconception may also be reinforced by frequent references in uninformed media sources to one person "feeling" another staring at them.

Concept Area 3: What is the Connection Between Light and Colour?

Although all the students recognised that a coloured filter would change the perceived colour of a light globe, none were able to offer a correct explanation. Most students considered that the cellophane changed the colour of the light globe. These findings are consistent with those of Karrqvist and Anderson (1983) and Fetherstonhaugh (1987). There is nothing in the Western Australian curriculum materials which clearly explains the relationship between colour and light. Cellophane is used as a filter in Year 3 but there is no explanation of what actually happens.

No student gave a correct answer when asked about the effect of a green light shining on a red box and 70% considered that the colour of the light and the colour of the box would mix resulting in a new colour. This misconception was also found in students investigated by La Rosa et al. (1984). The remaining students considered the box would take on the colour of the light or remain red.

Seventy-two percent of students considered that colour was the property of an object, a finding which was also recorded by La Rosa et al. (1984), Eaton et al. (1984) and Fetherstonhaugh (1987).

This concept is not covered in the Western Australian curriculum materials. Everyday language

tends to reinforce this misconception as we refer to a green book, rather than the book that reflects green light into our eyes.

Concept Area 4: Can Animals See in the Absence of Light?

Many students considered that animals are able to see in the absence of light after their eyes have adjusted to the dark. Sixty-seven percent believed a cat can see in total darkness, 81% believed an owl could see in total darkness and 58% believed that people can see in total darkness. Featherstonhaugh (1987) found that 55% of Western Australian high school students considered that cats could see an object in total darkness, but only 10% of his sample considered that people can see in the dark. His questionnaire did not refer to a prolonged stay in total darkness. Most people do not have the opportunity of experiencing total darkness and one student who had was definite in his view that it was impossible for a person to see in total darkness. Once again, everyday language which states that "cats can see in the dark" and "wait until your eyes get used to the dark" tend to reinforce the misconception.

The misconception that the moon would have an adverse effect on an owl's eyesight, or no effect on an owl's or cat's eyesight reinforces the students' lack of understanding of the physical process of sight. This

misconception may be related to the fact that many students were aware that owls do not like daylight. It is also possible that the children have never had the opportunity to notice or have never consciously noted the difference in visibility between a moonlit and moonless night nor do they have scientifically valid information about nocturnal animals.

Night vision is not part of the primary science curriculum but the fact that these misconceptions are present poses problems for secondary science teachers.

Concept Area 5: How Far does Light Travel?

This topic was covered in some detail in the interviews and only one student in one situation felt that light would continue travelling indefinitely. All students believed that light would travel a limited distance in the majority of situations with between 19% and 67% considering it would travel less than a metre depending on the source. Fetherstonhaugh (1987) found similar misunderstandings with his subjects when questioned about light from a globe and car headlights although some students had correct understandings. Stead and Osborne (1980) found children unable to correctly define how far the light from a candle would travel, and Karrqvist & Anderson (1983) found between 62% and 68% of students, depending on their age, had similar misconceptions.

Analysis of students' answers indicated they

believed that a stronger or brighter light would travel further, a misconception also reported by Stead and Osborne (1980). To most people, children and adults, a brighter light would be seen from further away, particularly when looking at examples such as lighthouses, where an apparently large light is used to ensure the light is seen at a distance.

All but one student considered it possible to see a light source without the light reaching the viewer. As viewers are unable to see any effect of the light locally they would assume that the light is not reaching them, a misconception also reported by Stead and Osborne (1980).

Many students believed that light travelled less far during the day than during the night. This was also recorded by Fetherstonhaugh (1987) and Stead and Osborne (1980). This may again result from personal observation as light during the day often does not appear to reach as far and no reflection of the light can be seen.

This discussion demonstrates the relationship between the misconceptions held by Western Australian primary students and those overseas or in Western Australian high schools, and the possible relationship of those misconceptions with personal experience and learning. The implications of these findings are discussed in chapter 6.

CHAPTER 6

Summary and Conclusions

It would appear from this study that Western Australian primary students have many misconceptions about light and vision. The misconceptions identified in this sample of Western Australian primary students are similar to those identified amongst primary students overseas (Eaton et al., 1984; Karrqvist & Anderson, 1983; La Rosa et al., 1984; Stead & Osborne, 1980) and amongst high school students in Western Australia (Featherstonehaugh, 1987). We can only speculate on the origins of these misconceptions. Some may arise as a consequence of inadequate or ambiguous information in the suggested curriculum materials, but they may also be due to the fact that the scientific concepts of light and colour are often poorly understood by many adults. Misconceptions are unconsciously reinforced by adult phraseology and actions, everyday sayings, urban myths, literature, the media and by students' own intuitions.

Summary of Findings

The following misconceptions were found to be held by 25% or more of the students:

Concept Area 1: How do people see?

- (a) The sun gives light enabling people to see.
- (b) Sunlight/light brightens/lightens things so they can be seen.

Concept Area 2: Is it Possible to Feel Someone Staring at You?

- (a) It is possible to feel someone staring at you even if you are unable to see that person.

Concept Area 3: What is the Connection Between Light and Colour?

- (a) The red cellophane makes the light globe look red.
- (b) When a green light is shone on a red box either the colour of the box or the colour of the light is still visible.
- (c) When a coloured light is shone on an object the colour of the object and the colour of the light mix to produce a new colour.
- (d) Colour is the property of an object.

Concept Area 4: Is it Possible for Animals to See in the Absence of Light?

- (a) Owls and cats can see at night.
- (b) The light from the moon makes it harder for an owl to see.

- (c) The light from the moon makes no difference to the owl's or cat's ability to see.
- (d) Some animals can see in the absence of light.
- (e) If a person or animal stays in a lightless environment for a period of time their eyes will adjust and they will be able to see.

Concept Area 5: How Far Does Light Travel?

- (a) Even if there is nothing in the way which would stop the light travelling, light will only travel a limited distance.
- (b) The strength of the light affects the distance it will travel.
- (c) It is possible to see a light source without the light reaching you.
- (d) The distance light can travel diminishes if there is another light source available which appears stronger.

Although these understandings have been referred to as misconceptions, in view of the age and developmental level of the students, it is probable that some are the result of incomplete knowledge rather than true misconceptions. The understandings which might fall into this category are 1(a), 1(b), 3(a), and 3(d).

Implications for Instruction

Primary school teachers require a knowledge of concept development in children to ensure that science topics are taught effectively. This would also produce an awareness that specific understandings, e.g. colour is the property of an object, are acceptable at their developmental level but will need to be taken into consideration in future learning situations.

It is essential that primary science curriculum materials be examined carefully and inadequate or ambiguous wording rectified. Background information must be in easily understood, non-scientific language, particularly as many primary teachers have a non-science background. The materials should be amended to include information about likely misconceptions and how to test students for them, as well as activities to alleviate misconceptions which may be found.

Curriculum material for the new Health Syllabus also includes ambiguous information regarding light and vision. The materials need to be revised.

Children's misconceptions of light are likely to be poorly understood by many primary teachers. The topic of misconceptions in general as well as specifically about light should be a focus of attention for inservice courses and seminars.

If students continue going into high school

science classes with significant misconceptions, it will be necessary for high school science teachers to address these misconceptions as part of teaching about light. It is likely that few high school teachers are aware of the problem and they would need to develop the skills to ascertain the misconceptions children have and then adopt a conceptual change strategy to eliminate them.

Implications for Future Research

This research only covered a limited number of students in a small area of Perth. Overseas research indicates that the misconceptions found in this sample are probably widespread. A pencil and paper test needs to be developed that will indicate the presence of misconceptions and which can be easily used and analysed by primary and secondary teachers.

A new primary school science curriculum about light which would recognise and alleviate these misconceptions should be developed and tested. This needs to be made available to all primary schools.

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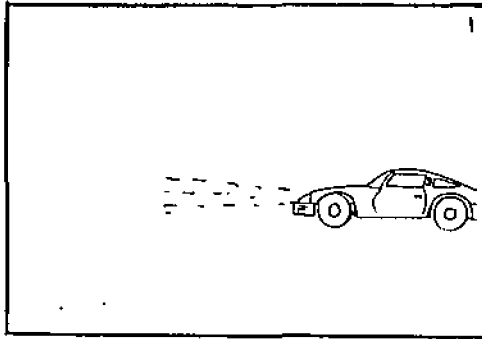
APPENDIX 1

Cards and Focus Questions used in Interviews

Cards and focus Questions used in Interviews

Note: Where colour was relevant to the question it was shown on the card

Card 1

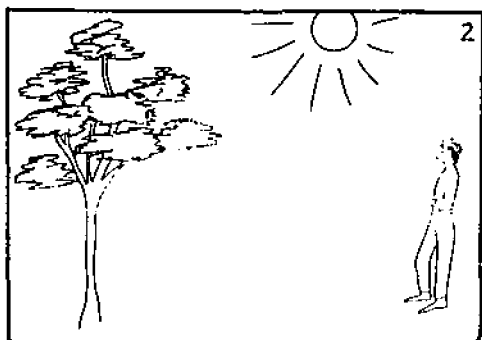


How far would the light from the headlights reach?

If the headlights were pointing straight up into the air, how far would they reach?

If there was a very bright moon would that make any difference to the distance that light from the headlights travelled? What is happening to make that difference?

Card 2



What is happening so that the person can see the tree?

Do you know what actually happens so that people can see? What happens with their eyes?

Card 3/4



Can the owl/cat see the mouse at night?

If there was a full moon would it make it easier or harder for the owl/cat to see or wouldn't it make any difference?

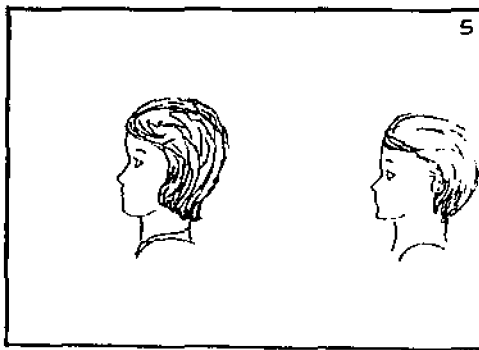


If I took that owl/cat and put it in a room with no windows and the doors were shut tightly so there was no light getting in at all, could the owl/cat still see the mouse?

No Card

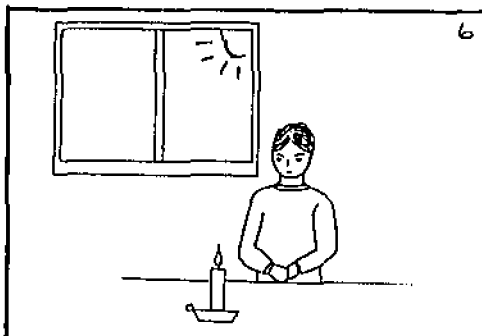
If I took you and put you in that pitch dark room, remember there is no light getting in at all, could you see anything?

Card 5



Is there any way the person in front knows that the person behind is staring at them?

Card 6

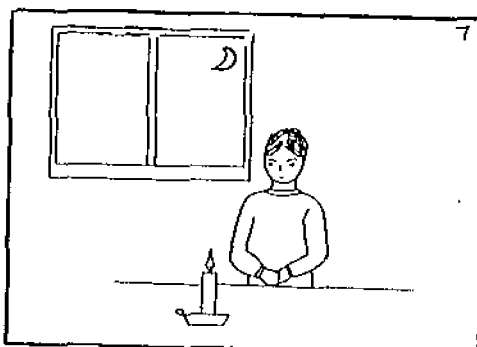


How far do you think the light from the candle will reach?

If I was further away than (distance) would I still be able to see the candle?

If we took the candle outside during the day would it make any difference to the distance the light travels? What sort of difference would it make, would it travel less far or further? What is happening to make that difference?

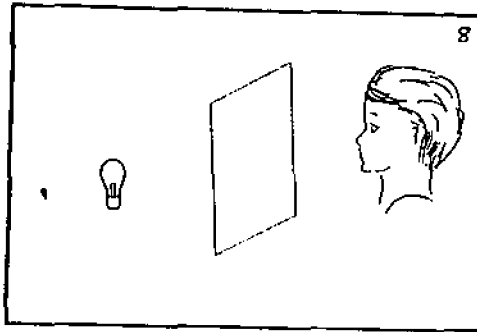
Card 7



How far do you think the light from the candle will reach?

If I was further away than (distance) would I still be able to see the candle?

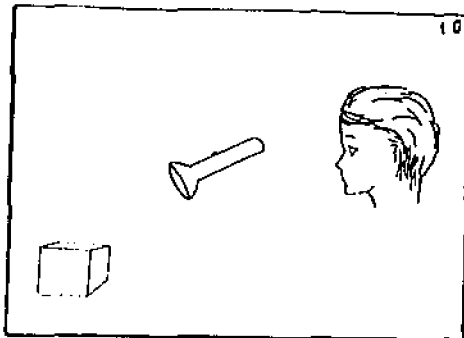
Card 8/9



If you look through red/green cellophane at an illuminated light globe what do you see?

Why does the light globe look red?

Card 10/11/12



If you were in a dark room and you had a really good torch shining a clear white light and you shone it on a red box, what would you see?

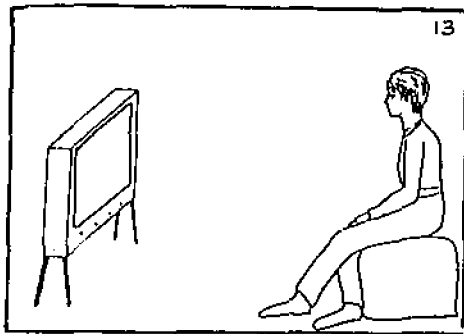
If we were still in that dark room and we shone a red light on the red box what would we see then?

If we were still in that dark room and we shone a green light on the red box what would we see then?

No Card

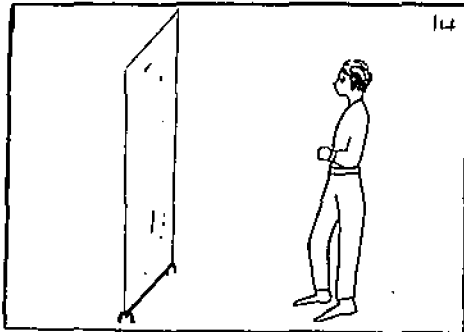
There's a *colour/object* over there. Can you tell me why we see it as that particular colour?

Card 13/14



How far do you think the light from the television/mirror will reach?

If I was further away than {distance} would I still be able to see the television/mirror?



If we took the television/mirror outside during the day, would it make any difference to the distance the light travels? What sort of difference would it make, would it travel further or less far? What is happening to make that difference?

If we took the television outside at night, how far would the light reach?

APPENDIX 2

Light Related Topics in Education Department Curriculum Materials

List of Light Related Concepts Found in Education

Department Curriculum Materials

Note: The materials for Years 1 - 4 do not teach specific concepts but are aimed at developing children's skills and are so worded.

Year 1: Topic - Colour

The activities suggested in this topic are aimed at developing children's skills in:

1. RECOGNIZING and NAMING common colour groups - reds, blues, yellows, ...
2. CLASSIFYING according to colour.
3. OBSERVING and DESCRIBING the effects of combining colours.
4. RECORDING activities.

(Curriculum Branch, Education Department of Western Australia, n.d. p. 93).

Year 2: Topic - Light

The activities suggested in this topic are aimed at developing children's skills in:

1. RECOGNIZING which one of our senses detects light.
2. DESCRIBING and CLASSIFYING light sources.

3. OBSERVING that light affects visibility.
4. OBSERVING and making shadows.
5. OBSERVING and CLASSIFYING substances according to the amount of light they absorb.
6. RECORDING activities in a variety of ways.
(Curriculum Branch, Education Department of Western Australia, n.d. p. 35).

Year 3: Topic - Light

The activities suggested in this topic are aimed at developing children's skills in:

1. OBSERVING and DESCRIBING sources of light.
2. RECOGNIZING that light can be emitted or transmitted (reflected).
3. RECOGNIZING and DESCRIBING the colours of the spectrum.
4. OBSERVING and INFERRING how translucent materials can affect the colour of light.
5. RECOGNIZING some aspects of light refraction.
6. OBSERVING and RECORDING symmetry in objects.
(Curriculum Branch, Education Department of Western Australia, n.d. p. 69).

Year 5:

1. Shadows are affected by:
 - (a) the shape and size of the object,
 - (b) the relative positions of the light source, and the object.
 2. The length and direction of the shadow cast by an object on a sunny day is relative to the position of the sun and hence to time.
 - (3) The clarity of a shadow is dependent on:
 - (a) the intensity of the light,
 - (b) the relative position of the light source,
 - (c) the degree of opaqueness of the object,
 - (d) the colour and/or texture of the screen.
- (Curriculum Branch, Education Department of Western Australia, n.d. p. 7).

Year 7:

1. Light is a form of energy which:
 - (a) can be detected and measured by our eyes;
 - (b) can be transmitted, reflected and/or absorbed.

2. The amount of light transmitted, reflected and/or absorbed depends on the properties of the surface which it strikes.
3. Practical use can be made of substances which effectively reflect, transmit or absorb light, e.g. mirrors, periscopes, window panes, welding goggles, ...

(Curriculum Branch, Education Department of Western Australia, n.d. p. 67).

APPENDIX 3

Sample Interview Transcript

Transcript of Interview With Student 38F7

- I Okay, the first picture is a car, it's night time the car's stationary, the headlights are on full beam. About how far do you think the light from the headlights is going to reach?
- S Um about 10 metres.
- I About 10 metres. Would it make any difference if the moon was full, if we got one of these really big, bright full moons?
- S Oh, it would probably make the light look like it was going a little bit less because the sun would be bright and overpowering the headlights.
- I Okay, you said it would look as if the light was going a bit less.
- S Mmm.
- I Would it be going less or would it just look as if it was going less?
- S It would look as if it was going less.
- I So it would still be going the 10 metres?
- S Mmm.
- I But you wouldn't be able to see it. Okay. If I jacked that car up so it's pointing right up into the sky so that the headlights were going straight up about how far would they go then?
- S Oh, probably a little bit more than 10 metres.
- I Why do you think it would go further when it's pointing up?

- S Well, there's a lot more maybe there wouldn't be any trees around it would be a lot clearer and it would be also a lot darker so it would look going further and it probably would go further.
- I Yeah. Okay, you said there wouldn't be trees there's nothing in the way. If this light was actually pointing so there wasn't any thing in the way at all, um it was above the road so it wasn't going to hit the road and there weren't any trees or people in the way so it could just keep going, would it go the same distance as it would pointing up, more than 10 metres or would it still only go about 10 metres?
- S It would probably go the same but as the moon's shining it would look like it was going less.
- I Okay, we've got somebody in the daytime looking at a tree. Now if it was night time he couldn't see the tree. What happens in the daytime so that he can see it?
- S Well, the sun's shining so it gives him the extra light to have a look at the tree.
- I Okay. Do you know what actually happens to him to see, what happens in his eyes, anything like that? How he actually sees?
- S Well not very much, no.
- I You don't, Okay. I've done most of the people I've talked to haven't known very much about that so

don't worry about it. There's an owl, it's night time and there's a mouse. Can the owl see the mouse?

S Yes.

I Why can the owl see the mouse at night?

S Well, because he's got specially designed eyes that actually see better in the night better than we have because the pupils get a bit larger so that he can see properly.

I Okay, if the pupils get larger what what happens, do do you know what good that does?

S Its lets the um it lets him focus a bit more.

I Okay. If there was a very big bright moon would that make it easier for the owl to see or harder?

S Well I think it would make it a little bit easier because they'd have the light but also it might make it a little bit harder as the pupil would get probably a bit smaller.

I Okay, so it would make a little bit of difference. If I took the owl and I put him in a room and it didn't have any windows and the doors were shut so it's pitch black in there, there's no light getting in there at all could the owl still see the mouse?

S Er probably because he has different eyes to us.

I Okay. This ones very similar but this time we've got a cat looking at the mouse at night. Can the cat see the mouse?

S Yes.

I Can the cat see it as well as the owl? Is it the same as the owl?

S Well, the owl can probably see better because the owl goes to sleep during the day and so he'd be more used to the night than the cat would be more used to the day and the night.

I Okay, again, if we had a really big bright moon would that help the cat?

S It would probably help the cat more than it would help the owl.

I And if we put the cat in the very dark room could the cat see the mouse?

S Probably, but not as well as the owl.

I Okay. If I put you in that very dark room, apart from being terrified, would you be able to see anything? Remember, there's no light coming in at all.

S No, I probably wouldn't be able to see anything.

I If you stayed in there for a little while would that make any difference?

S Yes, because my eyes would get used to the light, and I might start to see shapes but not as well as the cat or the owl.

I Yeah, okay. I've got somebody staring at the back of somebody's head. Is there any way this person in front knows that the other person is staring at them?

S Well I guess you can sense someone behind them, but, you sort of have a feeling, but there's no real way, unless they have a mirror or something.

I Okay. It's just a feeling. Has it happened to you? Have you felt people staring at you?

S Yes.

I What does it feel like?

S Well it feels like there's something wrong and you try to check and make sure there's nothing wrong with you.

I What do you think gives you the feeling?

S Well maybe you were thinking about something, and then all of a sudden you realise that maybe they heard you or something like that and so you think that they're staring at you.

I Yeah. You don't think there's something coming from this person that's making this person feel them. You know they sort might be sitting there thinking 'I'm staring at you' you know.

S Well. I guess if it's strong enough it might be able to, but, er, I don't think so.

I You don't think so. Okay. If we've got a candle in room during the day how far do you think the light from the candle would reach?

S Um. Probably not very far because the sun would be brighter than the candle.

I Okay, about how far do you think. That far. Or a metre, or a couple of metres, or..?

S Oh probably quite um probably about a metre or maybe less but a metre.

I A metre or less. Ok. If we took the candle outside in the playground area. Really bright sunshine. Would it still travel about a metre?

S Probably not because there'd be more light and the sun would be really overpowering the candle.

I Okay. If we had the candle in the room at night, would it still travel a metre or do you think it would travel further?

S I think it would travel a lot further.

I Okay. Lets take an average sized room, a room at home, would it reach the walls of your room at home, do you think? The light?

S Yes.

I And about how far would that be about? Three metres? If you had the candle in the middle of the room.

S Yep.

I Okay. If we had a room, this one is obviously more than three metres, and the candle was here. Would the light reach that wall over there, do you think?

S Oh, maybe not as far as that, but probably at least three quarters.

I About three quarters of the way. So that would be about five metres I should think something like that. Um, If I was standing over there could I still see that the candle was lit?

S Yes. You'd be able to see that the candle was lit.

I Yeah. Okay. But the light wouldn't actually reach the wall.

S No.

I Okay. If we took the candle outside at night. Do you think it would still go about that five metres? Or further or not so far?

S Well, it'd probably be darker outside. So, we might have it travelling a bit further than the five metres.

I Mm. Okay. Not a lot further though?

S No.

I Um. Okay now during the day it's only going about a metre and at night it goes a lot further. Why doesn't it go as far during the day?

S Well. Because the sun is brighter than the candle, so the sun is like overpowering the candle's light. So it seems like it's going less.

I It seems like it's going less.

S Well. It'd probably be going, maybe a little bit less than at night, but it would only seem like it's going a short way because of the sun.

I Okay. So you think it might go, perhaps four metres. But you couldn't see it. Is that what you're trying to say?

S Yeah.

I Yeah. Okay. But it still wouldn't go quite as far as it does at night?

S No.

I Okay. We've got somebody looking at a lit light globe through a piece of red cellophane. About how far... Sorry I'm still not focussed on these questions. What is he going to see?

S Well, he's going to see the light bulb, but he's going to see it with a red tinge.

I Okay. A bright red tinge? Or dark, or just a little bit red.

S Well I guess how close you put the light bulb to the cellophane would determine that.

I Okay. Do you know why it looks red? Why the light globe's going to look red?

S Well the red cellophane is partly transparent, but it's also got some red in it. So it'll make the light and the light bulb look red.

I If we were looking at green cellophane, looking through green cellophane, what would you see then?

S Same light bulb but with a greenish tinge.

I A greenish tinge and it'd be the same reason?

S Yes.

I We're in a dark room and we've got a red box and we've got a really powerful torch, a really good torch, so the light is bright and it's very clear light what would we see if we shone if we shone the torch on the box?

S Oh..just a red box.

I If we put a piece of red cellophane over it so it's a red light coming out this time what would we see this time?

S Well the red light would be a little bit darker and also there'd be a bit of a red shadow, bit of red light around the box.

I A glow around it, is that what you mean?

S Yes.

I Yeah, Okay. If we changed it to a green light this time on the red box what are we going to see this time?

S Well the red wouldn't be as clear it'd be a reddish green colour and it'd have a green glow around it.

I Okay. When you're watching television, the television's on, there's light coming from the television, about how far do you think that light reaches.

S Well it reaches about 3 metres, or maybe even more, 3 to 5 metres

I 3 to 5 metres. If you were more than 5 metres away could you still see the television was on?

S Yes.

I Yeah. If we took the television outside, and this sounds a ridiculous question, during the day we took the television outside will the light still reach that 3 to 5 metres?

S It probably would but we wouldn't notice it that it was reaching that far.

I Yeah. So the sun would be stopping it, same as the candle.

S Mmmm.

I If we took it outside at night would it make any difference?

S Yes, you'd be able to know that it was reaching the 5 metres.

I Yep. It wouldn't go any further? Still be about the same.

S I think it would still be about the same.

I Okay, when you're standing looking in a mirror there's light coming off the mirror. About how far does the light from the mirror reach. You're indoors. You're standing there looking in the mirror.

S Oh probably about 2 metres.

I About 2 metres, a bit less than the television

S Mmm.

I Okay, if you were further than 2 metres away say the mirror was over there and I was sitting here the light wouldn't be reaching me because it'd be too far away.

S Yes.

I Yeah, but I could still see that my reflection in the mirror?

S Yes.

I Okay, if we took the mirror outside would it still reach the two metres?

S It probably would but you just wouldn't notice.

I You wouldn't notice it. Have you ever got hold of a mirror or something shiny and reflected the sun?

S Yes.

I About how far does that light reach?

S Umm very far it can reach about 20 metres or more.

I It can go a long way when you're doing that.

S Yes.

I Okay, right last question. You've got a is that red or orange your skirt?

S Oh, red.

I Red. Okay. You're wearing a red skirt. Do you know why it's red. Why it looks red?

S Umm because when it's dyed it has a red dye so the white material becomes red.

I Okay.

APPENDIX 4

Tables Showing Student Responses to Focus Questions

List of Tables

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5a - 11a	Tables Relating to Concept Area 3: What is the Connection Between Light and Colour?	98
12a - 15a	Tables Relating to Concept Area 4: Can Animals See in the Absence of Light?	101
16a - 18a	Tables relating to Concept Area 5: How Far Does Light Travel?	104

Tables Showing Students Responses to
Focus Questions

Concept Area 1: How Do People see?

Focus Question

What is happening so that that person can see the tree?

Table 1a

Student Responses (n = 37) to the Focus
Question by Percentage

Acceptable explanation	Incorrect explanation
8	92

Focus Question

Do you know what actually happens so that people can
see? What happens with their eyes?

Table 2a

Student Responses (n = 36) to the Focus
Question by Percentage

Acceptable explanation	Incorrect explanation	Did not know
8	39	53

Concept Area 2: Is it Possible to Feel Someone
Staring at You?

Focus Question

Is there any way the person in front knows that
the person behind is staring at them?

Table 3a

Student Responses (n = 37) to the Focus
Question by Percentage

Yes	No	Maybe
35	62	3

Focus Question

I've heard people say 'I could feel someone
staring at me'. Do you think that can happen?

Table 4a

Student Responses (n = 24) to the Focus
Question by Percentage

Yes	No	Maybe
42	50	8

Concept Area 3: What is the Connection Between
Light and Colour?

Focus Question

If you look through red/green cellophane at an illuminated light globe what do you see?

Table 5a

Student Responses (n = 37) to the Focus
Question by Percentage

	Correct response	Incorrect response
Red Cellophane	95	5
Green Cellophane	97	3

Focus Question

Why does the light globe look red?

Table 6a

Students Responses (n = 37) to the Focus
Question by Percentage

Correct explanation	Incorrect explanation	Didn't know
0	97	3

Focus Question

If you were in a dark room and you had a really good torch shining a clear white light and you shone it on a red box, what would you see?

Table 7a

Students' Responses (n = 37) to the
Focus Question by Percentage

Red	Other
92	8

Focus Question

If we shone a red light on the red box, what would we see then?

Table 8a

Students Response (n = 37) to the
Focus Question by Percentage

Red	Other	Didn't know
84	13	3

Focus Question

If we shone a green light on the red box what would we see then?

Table 9a

Students Responses (n = 37) to the Focus Question by Percentage

Correct	Incorrect	Didn't know
0	92	8

Table 10a

Student Responses (n = 34) by Suggested Colour, by Percentage

Red	Green	Mixture of red and green	Other
15	15	26	44

Focus Question

There's a (colour/object) over there. Can you tell me why we see it as that particular colour?

N.B. The object chosen, and consequently the colours, varied with the locations of the interviews.

Table 11a

Student Responses (n = 32) to the Focus Question by Percentage

That is its colour	Limited knowledge	Didn't know
72	12	16

Concept Area 4: Can Animals See in the Absence of Light?

Focus Question

Can an owl/cat see a mouse at night?

Table 12a

Student Responses (n = 37) to the Focus Questions, by Percentage

	Yes	No	Didn't know
Owl	94	3	3
Cat	78	19	3

Focus Question

If there was a full moon would it make it easier or harder for the owl/cat to see or wouldn't it make any difference?

Table 13a

Student Responses (n = 37) to the Focus Questions by Percentage

	Easier	Harder	No difference	Didn't know
Owl	27	27	40	6
Cat	70		27	3

Focus Questions

If I took that owl/cat and put it in a room with no windows and the doors were shut tightly so there was no light getting in at all, could the owl/cat still see the mouse?

If I took you and put you in that pitch dark room, remember there is no light getting in at all, could you see anything?

Table 14a

Student Responses to the Focus Questions by Percentage

	Number	Yes	Probably	No	Didn't know
Owl	37	49	11	35	5
Cat	37	19	5	73	3
Person	36			97	3

Focus Question

If I left the owl/cat/person in there for 10 - 15 minutes would that make any difference?"

Table 15a

Student Responses to the Focus Questions
by Percentage

	Number	Yes	No	Not sure	Didn't know
Owl	19	64	10	16	10
Cat	30	60	17	13	10
Person	36	58	31	8	3

Concept Area 5: How Far Does Light Travel?

Focus Question

How far do you think the light from the car headlights/candle/television/mirror will reach?

Table 16a

Student Perceptions (n = 37) of the Distance Travelled by Light from Various Sources by Percentage

Source	Distance travelled in metres					
	0	<1.0	1.1-10	11-100	101-1000	>1000 Infinity
Car lights. night			32	51	11	3 3
Candle, day inside	11	57	16		3	
Candle, night inside		19	51		3	
T.V. inside		27	57	5		
Mirror	3	22	35	3		

Note. Students not shown on the chart did not clearly define the distance the light would travel.

Focus Question

If I was further away than (*distance*) would I still be able to see the television/mirror/candle?
Note: The distance quoted would be the distance the student had suggested light would travel.

Most students (n = 31) were asked about the television, two about the candle and one about the mirror.

Table 17a

Student Responses (n = 34) to the
Focus Questions by Percentage

<hr/>	
Yes	No
<hr/>	
97	3
<hr/>	

Focus Questions

If we took the candle/television/mirror outside during the day would it make any difference to the distance the light travels?

If there was a very bright moon would that make any difference to how far the light from the headlights travelled?

Table 18a

Student Responses to the Focus Questions
by Percentage

	Number	No diff.	Less far	Further	Didn't know
Candle(a)	36	28	58	8	6
Candle(b)	36	11	86	0	3
Television	37	38	62	0	0
Mirror	32	40	25	16	19
Car	37	49	40	8	3

Note: The comparisons were:

Candle (a) Candle during the day inside to
 during the day outside.

Candle (b) Candle during the day inside to
 night time inside.

Television Television inside to outside during
 the day.

Mirror Mirror inside during the day to
 outside during the day.

Car Car on a dark night to car on a
 moonlit night.